NASA Earth Science Enterprise
Earth Science Applications Directorate
Food and Fiber Applications of Remote Sensing Program

Final Report:

Regional Change Monitoring of Habitat Reserve Systems with Very High Resolution Remotely Sensed Data

Project conducted by:
Department of Geography
San Diego State University
5500 Campanile Drive
San Diego, CA 92025-4493

Report prepared by:
Lloyd Coulter, Project Manager
Douglas Stow, Principal Investigator

Contributors to Report:
Allen Hope, John O'Leary, and Janet Franklin, Co-Investigators
Aaron Johnson, Elizabeth Witztum, Aaron Petersen, Pauline Longmire,
Alys Wall, and John Rogan, Graduate Assistants
Edward Almanza, Consultant

Report prepared for:
Earth Science Applications Directorate
National Aeronautics and Space Administration
John C. Stennis Space Center, MS 39529

January 28, 2003

Table of Contents

Tables

Figures

Executive Summary

Wildlife habitat is a natural resource that is increasing in its intrinsic and economic value to humans. This is particularly true in southern California where rapid population growth and urban expansion have reduced the areal extent and quality of wildlife habitat. Preserve systems are currently being developed to protect key portions of the remaining natural habitat. The success of these preserve systems will rely in part on the ability to monitor habitat quality within these landscapes over time.

The primary objective of this NASA Food and Fiber Applications of Remote Sensing (FFARS) study has been to develop, test, and transfer remote sensing and other geo-spatial technologies for monitoring the amount, condition and quality of wildlife habitat within reserve systems being established throughout southern California. The focus has been on the utility of multitemporal, multispectral digital image data captured at very-high resolution (VHR), (0.5 to 5 m spatial resolution), in visible and near infrared (V/NIR) wavebands for monitoring habitat condition and disturbance effects on Mediterranean-type shrublands and riparian zones.

Reliable and low-cost monitoring of land cover changes as small as a meter, over areal extents greater than 10 km^2 is one of the most difficult challenges in remote sensing, particularly for landscapes having substantial variability in terrain relief. Thus, an important research focus was the assessment of acquisition and processing requirements for producing high fidelity, multitemporal image data sets. This was particularly the case for airborne digital data that provide VHR imagery with a great amount of flexibility in time of acquisition, but can have highly variable geometric and radiometric characteristics between images captured over time. Our results show that the key factors for efficiently monitoring detailed changes in land surface cover and form are: (1) careful planning and execution of airborne image data collection and (2) precise image registration. The timing of repetitive imaging should be controlled to minimize differences in earth-sun-sensor geometry (e.g., same solar time, anniversary dates). This serves to minimize radiometric differences in multitemporal data sets. An integrated hardware-software system for planning and triggering capture of digital images enables frame locations to be matched over time. Frame matched image data sets help to minimize radiometric variability, but even more importantly, geometric variations from differences in earth-sun-sensor geometry. Frame-matched multitemporal images have similar geometric distortion patterns. This facilitates precise registration using simple image warping transformations based on semi-automatic control point generation. Less critical is date-to-date normalization of image radiometry, which can be adequately achieved through a histogram matching process that preserves the shapes of the original image histograms. Use of calibration panels with varying and known reflectance is also effective and feasible when normalizing image data sets with meter-scale spatial resolution. Several procedures that were developed through the project will contribute substantially to operational production of high fidelity, multitemporal image data sets.

A second research focus was on the utility of VHR multispectral image data for mapping trail disturbance features and quantifying indicators of habitat quality, such as bare ground cover and shrub cover. Relationships between image-derived spectral indices and field-measured cover

fractions were assessed. Spectral indices were found to explain up to 60% of the variation in bare ground and shrub cover, depending upon the index. In addition, minimum trail widths detectable using VHR multispectral imagery were investigated. In general, trail with widths on the order of a quarter to half of the sensor ground sampling distance were detectable, depending upon the linearity of the trail feature and the target-to-background contrast.

The other major research focus was change detection analysis with VHR multispectral data, in the context of detecting and identifying disturbance and recovery features, and changes in habitat quality. Such analyses were conducted for both airborne and satellite image datasets. Most of the research focused on refinements of per-pixel change analysis, because of the small size (in at least one spatial dimension) of important disturbance features (e.g., trails).

Multiple methods for detecting land cover/habitat quality change using VHR multispectral imagery were tested during the project. These included rapid, efficient, and largely automated methods of change detection such as multidate image overlay compositing, image differencing, and classification of difference images based upon signed difference magnitude thresholds, above or below which highlighted features are considered to represent real land cover change. These products were generated using multidate image digital number (DN) values, spectral vegetation indices (SVIs), spatial pattern indices (SPIs), and fraction images derived through spectral mixture analysis (SMA).

In addition to these largely automated change detection approaches, change vector classification techniques requiring interactive operator involvement were assessed. The change vector classification approach to change detection provided the greatest utility in terms of identifying and labeling land cover changes. Land cover changes ranged in size from a few square meters to several hectares. Detected features generally included localized changes in soil and vegetation condition and exposure, as well as natural variations in vegetation phenology. Interpretation of the change detection results in conjunction with visual inspection of the multitemporal imagery enabled identification of specific change types, such as: vegetation disturbance and associated soil exposure increase, shrub removal, urban edge clearing/maintenance, vegetation cover increase, invasive plant sprawl, fire scar and subsequent recovery, erosional scouring, trail and road development, and expansion of BMX disturbance areas.

Remotely sensed image and derived data products will provide valuable and relevant information for monitoring habitat condition and change. We prescribe a prototype monitoring system based on the premise that the most effective means for assessing the quality of habitat across southern California preserves is to detect changes in vegetation properties at three monitoring scales. Image data with 30 m spatial resolution will be most cost-effective for monitoring at the regional level (~5000 km^2). Image data with 1 to 5 m spatial resolution from commercial satellites should be utilized for monitoring of sub-regional reserve systems (~1000 km^2). Habitat changes can be quantified based on changes in image-derived measures over time, resulting in maps depicting "hot spots" of likely habitat change. Even more detailed (0.5 to 1 m resolution) commercially-available imagery from digital cameras mounted on light aircraft could be captured and analyzed for areas determined from the regional and sub-regional level monitoring to be "hot spots" of change.

Several projects are currently underway that represent significant steps toward implementing a remote sensing-based monitoring system for southern California preserves. The goal of establishing a fully operational monitoring system for NCCP preserves is close to being realized at the level of the individual preserve. Full implementation across regional and subregional preserve systems will require government mandates or strong incentives for active and continuous monitoring. In addition, participation, cooperation, and cost sharing on the part of the agencies and reserve managers will be necessary, if image-based monitoring programs are to become operational. Reduction of satellite/aerial image acquisition and processing costs will further increase the likelihood of widespread image-based habitat monitoring programs. The tools and techniques developed through this project should also be effective for other vegetation and land cover monitoring applications requiring high spatial detail.